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Materials, Tools & Technologies to Enhance Efficiency & the Green-Quotient of Smart Buildings

Utpal Kumar Nandy, Antara Nandy
B.U. Builders & Consultants Pvt. Ltd, Gwalior (M.P.) 474012, India
Email: bubuildersconsultants@gmail.com

Abstract— ***In today's modern world, buildings built using the principles of efficiency and sustainability have successfully been converted to a practical reality. Beginning with an explanation of the meaning of smart building, this paper will attempt to provide deeper insights into the concept. A study will be conducted to evaluate the key-players in smart buildings such as sensors, wireless networks and other internet of things. The research paper contains a detailed account on the numerous smart building technologies and materials developed for enhancing the efficiency of the buildings. However, such a technological revolution has its own share of challenges revolving around its impacts on the environment. Green buildings are used to refer to the buildings that incorporate naturally available materials for construction ultimately leading to zero carbon foot-print. This research is carried out to study the various ways to meet these targets. This paper contains a detailed explanation of the composition, properties and applications of such useful materials. The paper will present a description of the design criteria, workflow, operation and maintenance of the smart buildings incorporating those techniques that will provide optimal utilization of the facilities.***

Keywords— **Smart buildings, Sustainability, Building Information Modelling, Building Management System, Green Environment, Efficiency**

I. Introduction

"*The ideal building would be inexpensive to build, last forever with modest maintenance, but return completely to the earth when abandoned.*"— David Bainbridge

As the world moves forward in time, there is an increased impetus on digitalization owing to its manifold benefits to mankind. The building industry with its newly evolved smart buildings is no exception to this transformation. H. Singer and J.A. Powell of GSA Public Building Service define a Smart Building as one which "integrates major building systems on a common network" (NBS).

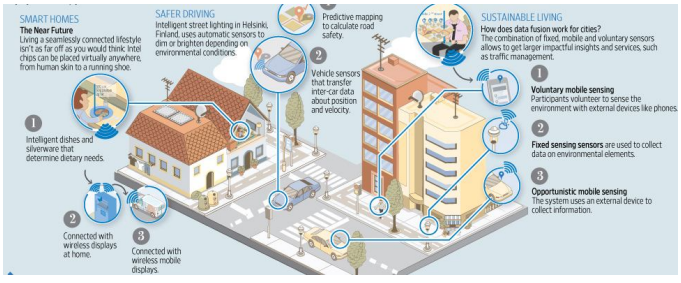
Smart building will make use of numerous technologies such as sensors, smart meters, smart power grids enabled with multi-energy support systems and so on. It is estimated that by the year 2020, approximately 50 billion networked sensors and appliances will be used in the world. With such rapid developments, the society will face newer challenges such as increased exposure to radiation. The building industry must prepare itself to incorporate more of such members that can themselves withstand this effect as well as provide a protective shield to the users. Moreover, these materials need to be cost-effective and readily available at the same time.

With growing awareness towards the sensitivity of the ecosystem, the concept of green buildings is rapidly gaining recognition. A green building is the one that is designed in such a manner that during its construction and in its lifetime of operation it effectively and optimally utilizes the available natural resources while being minimally dependent on the conventional energy sources. Green buildings not only consume resources but also generate and exports energy, materials and resources.

Examples of such efficient materials include radiation shielding glass-LX, bamboo, earth, compressed earth blocks and so on. These materials should be naturally occurring or require little industrial processing. The added advantage of these building materials is that they provide resistance from other hazards as well. For instance, bamboo is an excellent material that can also withstand seismic disasters. Compressed earth blocks are made up of clay-retaining earth and are then compressed into uniform building blocks. These possess heat-accumulating and moisture-regulating properties and can also neutralize smoke. A detailed understanding and analysis of the composition, properties and applications of such materials is necessary to promote their applications.

A green principles induced smart building will offer a dynamic and responsive architecture wherein every occupant is provided with productive, cost effective and eco-friendly conditions. It maintains a harmonious synchrony between the four essential components of the built environment namely, places, processes, people and management.

Fig 1: Smart Building and City (Urban Population Growth, 2012)



II. Smart Building Features

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Advances in the domain of data collection and analysis when incorporated in building construction have paved the way for smart building technology (Smart Buildings: People and Performance). The key-players in smart buildings include sensors, wireless networks and other internet of things. These sensors will be responsible for acquiring useful information about heat, light, spatial movement and space utility.

A smart building is enabled to support smart power grids to facilitate dynamic power consumption. The striking feature of these smart power grids is the ability to support all the renewable sources of energy for electricity generation along with the conventional sources. Smart power grids will have the facility to provide load forecasts, curtailment signals, capacity bids, dynamic electric rates and emission reduction information. Smart power grids require the smart meter installations in the buildings for power supply. These smart electricity meters make use of sensors to record energy expenditure and transfer this data to the provider as well as the occupants giving them the authority to regulate usage as per requirement. Such smart meters have already been put to practice in the commercials as well as households at UK (Khaund, 2013).

In Smart buildings, the Building Management System (BMS) is integrated with the enterprise method which is a web-based dashboard used to gather building-use information. This information is then fed into the Building Information Modeling (BIM) to incorporate live data in data structures to formulate efficient building design. The authorities will gain the control for sustainability and carbon foot-print management with the visibility to the overall picture of the organization irrespective of the number of buildings or inter-geographical separations. Information will be accessible quickly and easily.

- ***Building Information Modeling (BIM)***

Building information Modeling (BIM) is the technique of generating futuristic computerized simulation of the realistic situations created for a particular building employing the design elements. It will enable the designers, engineers, builders, users and other stakeholders involved in the process to deeply understand the working of the structure. It will help reduce the overall expenditure and energy by mitigating loses. Smart buildings need to expend resources based upon this information that it receives about numerous aspects such as the number of occupants, environmental conditions and also user feedback to create desired levels of comfort and energy-efficiency. Dynamically gathered data will promote reactive and anticipatory real-time alterations helping the occupants' desired indoor environment thus saving on energy through targeted supply. Expansion and up gradation of these wireless networks together with developments in the computing power will facilitate data availability. These in turn will enable strategic formulation for reducing the carbon footprint. The web based dashboard will display a visual snapshot of the energy usage by the appliances thereby detecting any abnormal maintenance costs or other situations demanding prompt attention (Khaund, 2013).

BIM acts as an information repository collectively for the geometry, special relationships, quantities and characteristics of the entire building mass, its energy expenditure and so on. It provides a common platform to all the stakeholders to take charge and bring about dynamic regulations. BIM will enhance information handling and smooth communications while averting clashes among different working groups. Consequently, it will bring down the overall construction cost due to elimination of data duplication (Sitharam).

Such a kind of advanced system will be particularly useful for the health sector where we will be able to develop optimum comfort conditions along with minimal energy usage.

- ***Maintenance***

Analysis algorithms are such tools that will be capable of detecting problem areas in performance before they cause expensive outages. This kind of proactive maintenance of the building members and equipments will help maintain optimum level of efficiency and management of the cost factor. However, it will call the need for identification of the authorities responsible for maintenance. The exact people responsible and answerable for the management systems need to be pre-defined to avoid last minute hassles. Moreover, since the entire system is based on information sharing and use, it is essential to develop more resilient systems that can withstand attacks by viruses, hacking and malicious software. Furthermore, the users need to be provided with technical and non-technical information to handle the well-equipped smart buildings and to address its requirements (Smart Buildings: People and Performance).

- ***Challenges***

An area of concern is the development of cheap and durable devices that can be powered by long range wireless sensors and can bypass congestion with the local ICT network signals and avert expensive wiring. Massive sets of data which is disparate and non-formatted in nature need to be managed such that useful data can be separated from the rest and can be utilized.

III. Green Building Materials especially usable in Smart Buildings

- ***Compressed earth blocks***

Earth is a precious natural resource with abilities of natural climatic regulation. Compressed earth blocks are non-fired, homogeneous building blocks which are compressed from the clay-retaining earth. Since they are not baked, the moisture-regulating and heat-accumulating properties of these blocks remain preserved. Walls made of these bricks absorb heat and moisture from hot and humid climate and releases them in cold and dry conditions. Furthermore, it neutralizes smoke and air-borne pollutants thereby refining the climate. Secondly, it helps insulate sound enhancing the acoustical properties of the building. The most significant characteristic of these compressed earth blocks is that it is non-inflammable and can neutralize mobile, DCET and cosmic radiation since

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they remain insensitive towards static electricity and electromagnetic fields (Compressed Earth Blocks-Living Building Material). Smart buildings will employ several such equipments that may expel radiation such as BIM devices but in the long run they will help to cut down on energy usage. Buildings built of the compressed earth blocks will mitigate the radiation effects on the users. Thus it is an invaluable gift of nature.

Fig. 2: Structure built using compressed earth blocks (Compressed Earth Blocks-Living Building Material)

- ***Bamboo***

Bamboo that has originated essentially from the glass family is amongst the fastest growing plants in the world. This plant is quite convenient to cultivate. Moreover, it can be given designs rather easily. Thus, it is both cost-effective and readily available along with other advantages like durability (Improving the use of energy in buildings). According to researches, the tensile strength of bamboo is comparable to that of mild steel. Therefore, due to its appreciable resistance towards tensile forces, bamboo becomes an ideal naturally available material for building construction. The greatest advantage of bamboo is its higher degree of resistance to seismic forces. Bamboo products act as shock absorbers since the energy that is released by earthquakes gets absorbed in their joints.

- ***Solar Photovoltaic Panels***

Green buildings will have the facility to incorporate conventional and non-conventional energy sources simultaneously for energy generation, therefore it is quite conducive to install solar PV panels and benefit from it. It is not necessary that the entire system has to be supported but whatever be the percentage of electricity generated it can be easily employed. Smart buildings will enable us to understand the amount of daylight received and the effective areas thereby helping the users to optimize the usage intelligently.

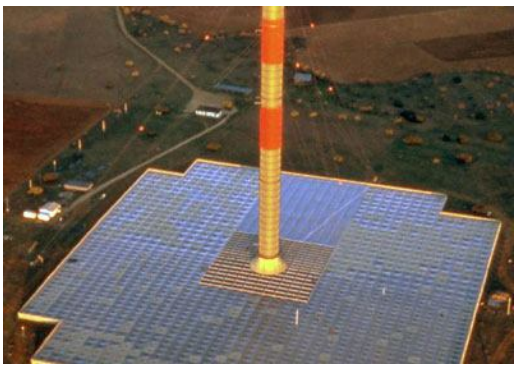

Fig. 3: Solar PV Panels

- ***Radiation Shielding Glass-LX***

It is employed in windows and protective screens to block x-rays and other radioactive materials. It allows high degree of light transmittance ensuring ample visibility. With the help of such a useful property, the glass can be successfully employed in high risk zones to mitigate exposure to harmful radiation

Furthermore, there are plenty of products that can be successfully developed from the industrial refuse as a product such as the paper bricks. Another way to enhance sustainability is to use the locally and abundantly available materials and also recycling of scrap metals such as steel and aluminium (Nandy, Nandy, & Nandy, 2015).

IV. Nanotechnology~

Nanotechnology is an evolving branch of science that deals with materials of the scale of 10^{-9}m to develop materials with new and improved properties. Certain nano materials such as silica, titanium dioxide and carbon nano tubes can significantly enhance the properties of concrete, steel, glass and other materials to generate desired characteristics like self healing, self cleansing, high strength, durability, thermal and fire resistance, corrosion resistance, stress reduction and other desirable properties (Agbenyeku, Muzenda, & Msibi, 2014). However, owing to their high cost and environmental concerns it has still not been employed in the construction industry at a large scale. In future, the benefits of nano materials may trigger intensive research in the field providing solutions to the existing challenges. In smart buildings, the efficacy of nanotechnology will act as a catalyst in promoting the utility and efficiency of the structures (Alsaffar, 2014).

V. Conclusion

In this race of rapid development, the construction industry will have to sooner or later embrace the smart buildings. Smart buildings offer promising solutions to efficient living environment where the occupants will exercise dynamic control over the facilities. However, at the same time is of immense importance that we acquaint ourselves with the pros and cons of the facility and prepare

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ourselves to face the challenges judiciously. However, apart from a mere incorporation of these elements it is essential to conduct a detailed study of the impact and inter-relationship of these elements and systems. It is necessary to carry out a careful re-evaluation of the available site features, integration of the materials and technologies and finally optimization of these resources.

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